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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :
G01B 11/27, G01C 5/00, 15/00, 15/10 | **A1**

(11) International Publication Number: **WO 95/08094**

(43) International Publication Date: 23 March 1995 (23.03.95)

(21) International Application Number: PCT/AU94/00557

(22) International Filing Date: 17 September 1994 (17.09.94)

(30) Priority Data:
PM 1281 17 September 1993 (17.09.93) AU

(71) Applicant *(for all designated States except US)*: JATCO (AUSTRALIA) PTY. LTD. [AU/AU]; 12-20 Hobsons Place, Adelaide, S.A. 5000 (AU).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: EDWARDS, Geoffrey [AU/AU]; 12-20 Hobsons Place, Adelaide, S.A. 5000 (AU).

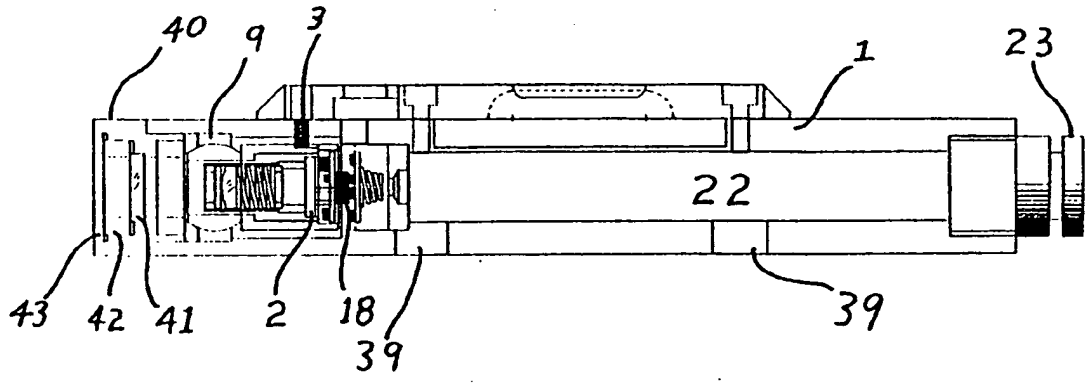
(74) Agent: A.P.T. Patent and Trade Mark Attorneys; G.P.O. Box 772, Adelaide, S.A. 5001 (AU).

(81) Designated States: AU, CA, CN, JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
With amended claims.

Date of publication of the amended claims:
4 May 1995 (04.05.95)

(54) Title: LASER ALIGNMENT TOOL



(57) Abstract

A simple, light and compact laser alignment tool has a precision multifaceted housing (1) with a laser diode (2) mounted within the housing. The laser beam emitted by the laser diode is adjustable to be coaxial with the elongate axis of the housing. A power supply (18) for the laser diode is also mounted within the housing and a spirit level (26) is mounted on the housing. A range of removable accessories are described which enhance the versatility of the laser alignement tool.

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AMENDED CLAIMS

[received by the International Bureau on 9 March 1995 (09.03.95);
original claims 1 and 5 amended; remaining claims unchanged (1 page]

1. A laser alignment tool comprising;
a lightweight, compact housing having a precision multifaccted body;
a spirit level mounted on the housing;
a semiconductor laser diode held inside an adjustable mount mounted within the housing and adjustable such that a laser beam emitted by the laser diode is coaxial with an elongate axis of the housing;
a power supply for the semiconductor laser diode mounted within the housing;
said semiconductor laser diode;
the adjustable mount being fixed in relation to the laser diode,
a first, emission aperture proximal, end of the mount or a second, emission being pivotable with respect to the housing about at least two transverse axes disposed orthogonally with respect to one another and each intersecting a path of said beam,
a position of a second, emission aperture distal, end of the mount being adjustable with respect to the housing about said at least two orthogonally disposed axes.

2. The laser alignment tool of claim 1 wherein the precision multifaceted body has a hexagonal cross-sectional geometry.

3. The laser alignment tool of claim 1 wherein the spirit level has a precision better than 30 minutes of arc.

4. The laser alignment tool of claim 1 wherein the semiconductor laser diode emits laser radiation at a visible wavelength.

5. The laser alignment tool of claim 1 whercin the adjustable mount incorporates a sub-mount adapted to hold the laser diode, wherein one end of the sub-mount is adapted to fit with interference fit into an inner portion of a precision spherical bearing, an outer portion of the said precision spherical bearing being adapted to fit with interference fit into the housing and wherein the adjustable mount is adjustable in orthogonal radial planes by threaded screws acting on an end of the adjustable mount.

6. The laser alignment tool of claim 5 wherein the emission aperture of the laser diode is referenced to the centre of action of the precision spherical bearing.

7. The laser alignment tool of claim 1 wherein the power supply comprises a DC power source and a hybrid surface mount circuit including a drive circuit and a control circuit.

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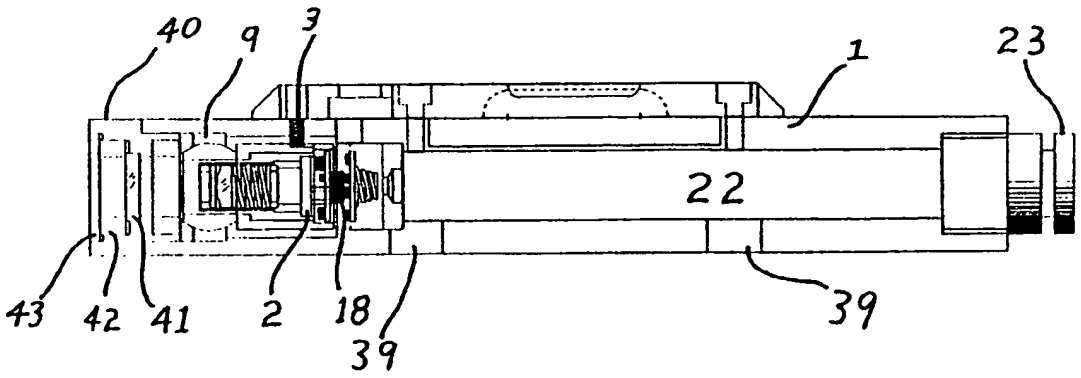
Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: LASER ALIGNMENT TOOL



(57) Abstract

A simple, light and compact laser alignment tool has a precision multifaceted housing (1) with a laser diode (2) mounted within the housing. The laser beam emitted by the laser diode is adjustable to be coaxial with the elongate axis of the housing. A power supply (18) for the laser diode is also mounted within the housing and a spirit level (26) is mounted on the housing. A range of removable accessories are described which enhance the versatility of the laser alignement tool.

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LASER ALIGNMENT TOOL

This invention relates to a laser alignment tool which is simple, light and compact compared to prior art devices. By an uncomplicated method the laser alignment tool can be quickly aligned by a person unskilled in laser technology. The laser alignment tool has a modular design so that it can be coupled with a range of accessories to perform a diverse range of functions.

BACKGROUND ART

A wide (and growing) range of laser level, laser plumb and laser alignment tools are known. Early devices (designed in the 1970's) were based on helium neon lasers and were quite large and cumbersome. Due to their size and power requirements the versatility of the devices was extremely limited. One such device is that disclosed in US Pat. No. 3897637 which describes a helium-neon laser based device which could project a beam both horizontally and vertically for levelling and squaring applications.

Self levelling mechanisms for these devices were also developed by a number of inventors. One example is found in US Pat. No. 3936197 which describes an arrangement in which a lens is mounted on a pendulum such that a light beam emitted from a laser source will be directed vertically by the lens despite the relative position of the laser.

More compact devices were produced in the 1980's as laser technology advanced and laser diodes became available. At the same time laser level devices became more sophisticated and incorporated self levelling mechanisms which operated to produce tilt-compensated horizontal or vertical beams. US Pat. No. 5075977 describes a compact but somewhat complicated automatic plumb, level and pointing tool which uses a visible laser diode and pendulum or cantilever mounted optics to produce a beam which is either vertical, horizontal or fixed relative to a housing.

The device of US Pat No. 5075977 and earlier devices described therein have concentrated on providing a laser level with a self compensating beam. Such devices have quite complicated mechanisms which increase the cost and limit the robustness. It is important that any laser alignment tool be simple, light and robust if it is to be generally accepted for use in the construction industry.

OBJECT OF THE INVENTION

One object of the present invention is to provide a laser alignment tool which is simple, light, compact and robust.

It is a further object of the invention to offer a modular device which can be easily modified to satisfy a range of applications.

It is a still further object to provide a laser alignment tool which is substantially cheaper and simpler to produce than prior art devices or at least to offer the public a useful alternative to existing devices.

DISCLOSURE OF THE INVENTION

In one form of the invention although it need not be the only or indeed the broadest form there is proposed a laser alignment tool comprising :
a lightweight, compact housing having a precision multifaceted body;
a spirit level mounted on the housing;
a semiconductor laser diode mounted within the housing and adjustable such that a laser beam emitted by the laser diode is coaxial with an elongate axis of the housing; and
a power supply for the semiconductor laser diode mounted within the housing.

The semiconductor laser is adjustably mounted to facilitate coaxial alignment with the housing. The alignment of the laser diode axis relative to the housing axis is preferably adjustable by adjustment means comprising a s -f adjustable mounting having two fine threaded adjustment screws mounted orthogonally in the housing and acting on one end of the adjustable mounting. The other end of the adjustable mounting is held in a spherical bearing located coaxially with the housing. The emission aperture of the laser diode is referenced to the centre of action of the spherical bearing so that adjustment of the laser diode mount moves the laser beam in the far field but remains coaxial in the near field. By this arrangement precision adjustment is possible.

In preference the housing is elongate with a cross-sectional shape of hexagonal geometry. Although hexagonal cross-section is preferred a greater or lesser number of sides is also acceptable. The inventor has considered pentagonal and octagonal bodies but has found that hexagonal offers maximum versatility. Furthermore, the hexagonal body is available as a standard extrusion thereby reducing costs of production and facilitating the use of the device in a range of applications with other standard equipment. The multifaceted nature of the body assists in the manual alignment process.

The elongate shape of the housing enhances the stability of the laser alignment tool in resting upon a surface. Many prior art devices have had very short bodies which could be affected by the unevenness of the surfaces they are used against. An elongate body minimises this effect.

In preference the spirit level is mounted on one elongate face of the housing and preferably has a precision of better than 30 minutes of arc.

In preference the semiconductor laser diode operates at a wavelength in the range 600nm to 800nm and preferably operates at a visible wavelength in the range 630nm to 650nm. These wavelength ranges encompass commonly available laser diodes. Emerging technology has led to laser diodes being available at other wavelengths in the visible region and these would be suitable for use in the laser alignment tool.

The housing preferably includes accessory mounting means adapted to mount a range of accessories to facilitate use of the laser alignment tool in one or more of the following applications : industrial alignment; laser level; laser square; laser plumbline; fibreoptic test head. The accessory head preferably incorporates a magnet for magnetic attachment of the accessory head to the laser alignment tool.

BRIEF DESCRIPTION OF THE DRAWINGS

To further assist in understanding the invention reference will be made to the following drawings in which :

FIG 1 is a side view of a laser alignment tool;

FIG 2 is an end view of the laser alignment tool of FIG 1;

FIG 3 is a top view of the laser alignment tool of FIG 1;

FIG 4 is a cut-away side view of the laser alignment tool of FIG 1;

FIG 5 is a cut-away end view of the laser alignment tool showing the laser diode alignment means;

FIG 6 shows an enlarged view of the laser alignment tool in the vicinity of the laser diode;

FIG 7 shows the method of coaxial alignment of the laser axis and housing axis;

FIG 8 shows schematically a plan view of a versatile mount for the laser alignment tool;

FIG 9 shows a side view of the mount of FIG 8;

FIG 10 shows schematically an accessory useful for coaxially aligning the laser alignment tool to a pipe;

FIG 11 shows schematically an accessory useful for externally aligning the laser alignment tool to a pipe;

FIG 12 shows schematically a plan view of a precision adjustment base for the laser alignment tool;

FIG 13 shows a side view of the mount of FIG 12;

FIG 14 shows an alternate embodiment of the mount of FIG 8; and

FIG 15 shows a penta-prism accessory.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings in detail there is shown one preferred embodiment of the laser alignment tool in which the housing 1 is elongate with an hexagonal cross-sectional shape (as clearly depicted in FIG 2). A hexagonal body enables definition of the housing axis thereby facilitating definition of the laser axis relative to the housing axis. Precision use of the laser alignment tool is dependent upon alignment of the laser output to the housing. Once the laser output and housing have been aligned to be coaxial the pointing accuracy of the laser beam can be used to ensure a remote surface or object is aligned with a surface with which the housing is in aligned contact.

Referring particularly to FIG 4 and FIG 6 it can be seen that a semiconductor laser diode 2 is adjustably mounted in the housing 1. Adjustment of the laser diode is made by adjustment of fine threaded screws 3 and 4 (shown particularly in FIG 5) acting on one end of an adjustable mount 5 containing a sub-mount 6 which in turn holds the laser diode, associated optics and associated electronics. A spring 7 provides adequate force to restore the module during adjustment and the orthogonal bevels 11, 12 provide a substantially linear and orthogonal adjustment.

The sub-mount 6 protrudes beyond the mount 5 and fits with interference fit into the inner portion 8 of a spherical bearing 9. The outer portion 10 of the spherical bearing is precision fitted into the housing so that the beam of the laser diode emanates from a point on the elongate axis of the housing. The laser is always collimated, notwithstanding the astigmatic effects of the laser.

Adjustment of the alignment of the laser output beam is possible to a precision set by the pitch of the adjustment screws 3, 4 and the distance of the screws from the spherical bearing 9. In the preferred embodiment this is equivalent to an adjustment of ATN(0.4/14) = 1.63 degrees per rotation. The setting precision of the preferred screws is approximately +/- 5 degrees, therefore the alignment precision is approximately 1.63/72 = 0.023 degrees or 0.04 milliradians. This is less than the beam divergence of commercially available diode lasers.

The laser mount comprising the spherical bearing 9, mount 5, sub-mount 6, laser diode 2 and associated electronics and optics can be used independently as an ultra-compact pointing device. The spherical bearing allows an angular adjustment over tens of degrees which the inventor envisages as very useful in automated production applications. When coupled with an optical detector the device could be used in a robotic vision role.

The laser is preferably a visible semiconductor laser operating at a preferred wavelength of 635nm although other wavelengths such as 670nm, 650nm or 615nm are optionally available. The output of the laser 2 is collimated by a single element moulded aspheric glass lens 13. The lens 13 is held in the sub-mount 6 by a locking ring 14 and spacer 15. A spring 16 seats against a plastic isolation ring 17 and acts against the lens 13.

The laser diode 2 is driven by a hybrid surface mount circuit 18 located in the sub-mount 6 behind the laser 1. The circuit 18 consists of a drive circuit 19 which directly powers the laser diode 2 and a control circuit 20 (commonly called Automatic Power Control or APC). The method of laser power stabilisation of the preferred embodiment uses the fixed laser diode voltage as a stabilising reference voltage for controlling photodiode feedback. The control circuit 20 can be configured to drive the laser diode in either a CW or modulated mode. In one embodiment this function is selected by touch sensitive switch 21. A modulation frequency of 2.8 +/- 0.2 kHz is selected as an accessible part of the audio frequency spectrum. The invention is not limited to any particular modulation frequency.

In another embodiment the control circuit is configured so that switch 21 performs an on/off function. In this embodiment the laser diode operates in a modulated mode.

The laser is powered by two AAA batteries (not shown) located in compartment 22 within the housing 1. The battery compartment cover 23 may act as an on/off switch by breaking contact with the battery terminal. The batteries are loaded in the same orientation as for a standard penlight. Reverse voltage protection is provided by the positive battery contact arrangement consisting of a shaped plastic seat 24 which only permits the positive battery terminal of AAA batteries to make contact with the spring 25. The spring 25 is in electrical contact with the control circuit 20. By virtue of its flexibility the spring maintains contact with the battery terminal throughout the range of adjustment of the laser diode.

In an alternative embodiment the device can be powered by an external AC to DC adaptor or rechargeable NiCad or Lithium batteries. The device may also be powered by solar cells such as those used in some calculators.

Embodiments powered by external power supplies or solar panels allow for a second laser mount (comprising the spherical bearing, mount, sub-mount, laser diode, associated electronics and optics) to be located in the other end of the laser alignment tool. This effectively doubles the range of the alignment tool by providing a pair of coaxial alignment beams, one emanating from each end of the tool.

The sub-mount 6 is heavily anodised to provide electrical isolation while allowing thermal contact. This enables the housing to provide the negative circuit return as with a penlight. Electrical connection between the housing and circuit is via compression spring 7.

The laser output beam can be aligned coaxially with the housing elongate axis by the alignment method depicted in FIG 7. The laser alignment tool is rested upon a flat surface, as shown in FIG 7A, pointing at a distant wall with a surface approximately perpendicular to the pointing direction of the laser beam. The position of the laser spot on the wall is marked, say by the letter A. The housing is then rotated onto another face, as shown in FIG 7B. A further spot, B, is marked. This procedure is repeated for spots C, D and E. Spots A and D, and B and E are joined and the intersection of the lines AD and BE is the position to which the laser beam is aligned. This technique ensures that the laser and housing can be quickly and accurately aligned by a person with no particular skill in laser devices. Once the laser is aligned to the housing the fine threaded screws 3 and 4 are cemented in position to minimise the possibility of loss of alignment.

By using the above procedure a user of the laser alignment tool can check the alignment of the laser at any time. If the laser is found to be misaligned from the housing it can be returned to the factory for realignment. Such a feature is important for a device which will suffer considerable shock and vibration during normal use on a construction site or other industrial application.

A spirit level 26 is mounted on the housing 1 to facilitate levelling of the laser alignment tool. In one embodiment, shown in FIG's 8 and 9 there is provided a tilting mount base 27 having a fixed plate 28 and adjusting plate 29. The base 27 is provided with coarsely adjustable feet 30 which are preferably detachable and there are magnetic mounts 31 provided as an alternative mounting means. The tilt of the adjustable plate 29 is adjusted in the conventional way by orthogonally acting adjusting screws 32 and 33. The adjusting plate 29 is provided with a circular spirit level phial 34.

The adjustable plate 29 also has two rare earth magnets 35 mounted flush with the upper surface. Corresponding magnets 39 on the underside of the laser alignment tool hold the laser in position on the plate. Fine rotational adjustment of the laser alignment tool is provided by adjustment cam 36 which acts against the side of the laser alignment tool. A cradle 37 holds the laser in place so it rotates about the centre of the plate 29. This arrangement provides approximately 10 degrees of adjustment.

In an alternative means of providing rotational adjustment the laser alignment tool can be located in a precision rotational mount 70 free to rotate on precision bearings 71 as shown in FIG 14.

The fixed base 28 is provided with a 5/8" Whitworth thread 38 for mounting on a standard surveyors tripod. By means of a simple adaptor the tilting mount base can also be mounted on a camera tripod or other telescopic tripod. The laser alignment tool may be mounted directly on to a tripod using the magnets 39 on the underside.

Other mounting arrangements are shown in FIG's 10 and 11 for use in bore-sighting applications. FIG 10 shows an arrangement for mounting the laser alignment tool coaxially with a pipe 44. The laser alignment tool is positioned in a mount 45 the internal diameter of which matches the external diameter of the housing 1 of the laser alignment tool. As a standard extrusion is used for the housing it is possible to obtain a larger standard extrusion of the appropriate dimensions. Fixed legs 46 and self adjusting leg 47 act to position the mount and therefore the laser alignment tool in the centre of the pipe. The length of the legs is chosen to suit the internal diameter of the pipe.

FIG 11 shows an arrangement for mounting the laser alignment tool on the outside of a pipe 49. The laser alignment tool is positioned in mount 45 and legs 48 are attached to the mount 45 as shown. In both cases shown in FIG 10 and FIG 11 the laser alignment tool can be used to ensure that pipes have the appropriate alignment and the correct slope relative to the horizontal.

A precision adjustment base for adjusting the tilting angle of the laser alignment tool is shown in FIG's 12 and 13. The adjustment base 50 comprises an elongate platform 51 having an adjusting screw 52 at a rear end and extending legs 53 at a forward end. The extending legs 53 have positioning feet 54 on an underside. The feet may be magnetic to assist in positioning of the base. The extending legs 53 can be folded against the base 51 for compact storage. The laser alignment tool 1 is positioned on the elongate platform 51 as shown and can be held in position magnetically as described above.

The adjusting screw 52 has a precision thread which provides a 0.33% change in grade for one revolution. The laser alignment tool 1 can be set to level using the spirit level 26 and then adjusted to the desired gradient by rotating knob 55.

An advantage of this invention is that a range of accessories can be easily attached to extend the versatility of the device. The accessories are contained in housings having the same type of precision multifaceted body as the laser alignment tool. One accessory 40 is shown attached to the laser alignment tool in FIG's 1, 3 and 4. The accessory 40 is a protective window comprising a glass window 41, a spacer 42 and a locking ring 43. The accessory 40 is held into the housing 1 by magnetic attachment between the outer portion 10 of the spherical bearing 9 and a magnet in the accessory. In an alternate form a conventional arrangement of ball spring plungers and seating holes can be used.

A range of other attachments may be provided to extend the flexibility of the laser alignment tool. Accessories include but are not limited to : beam splitting optics; right angle penta-prism; beam steering refractive optics; diffraction elements; and fibre-optic attachments for fibre testing. It will be appreciated that by virtue of the attachments the laser alignment tool can be used for industrial alignment, laser levelling, plumb line or squaring applications.

A side view of a compensated penta-prism accessory is shown in FIG 15. The accessory is assembled in a housing 80 of the same material and shape as the housing 1 of the laser alignment tool. An end 81 of the housing 80 has a reduced diameter so as to fit within the bore of the housing 1 of the laser alignment tool. A donut magnet 82 is located in the reduced end 81 and magnetically attaches to the precision spherical bearing 9. The penta-prism 83 is held in the housing 80 between a spacer 84 and locking ring 85. the penta-prism 83 generates a pair of orthogonal beams which are emitted through ports 86 and 87.

In a further embodiment the laser alignment tool can incorporate a safety interlock activated by the accessory. The safety interlock is in the form of a magnetically activated reed switch which only closes when an accessory head is attached to the laser alignment tool.

In a still further embodiment the laser alignment tool can be used with a photodiode detector unit. The detector unit is preferably fitted with a narrow band-pass filter to spectrally match the detector to the wavelength of the laser of the laser alignment tool. For added versatility the laser alignment tool can be operated in a modulated mode and the detector unit can be locked to the modulation frequency. This embodiment is particularly useful for surveying applications.

In a yet further embodiment the laser alignment tool can be waterproofed for underwater applications. Because the tool is totally self-contained it can be waterproofed by providing an O-ring seal between the battery compartment cover and the housing and by sealing the switch 21. In this embodiment the on/off function is provided by switch 21 rather than the battery compartment cover.

It will be appreciated that the laser alignment tool herein described is a simple, lightweight, robust device ideally suited for use in the construction industry. By virtue of its compact design it is easily transportable and can be carried around, for example, in a coat pocket or bag. By virtue of its modular design the device is extremely versatile and may be used as a level, a square, a plumb line or a fibre optic test head amongst other applications.

The preferred embodiments described herein are intended to illustrate the principles of the invention, but not to limit its scope. Other embodiments and variations to the preferred embodiments may be evident to those skilled in the art and may be made without departing from the spirit and scope of the invention.

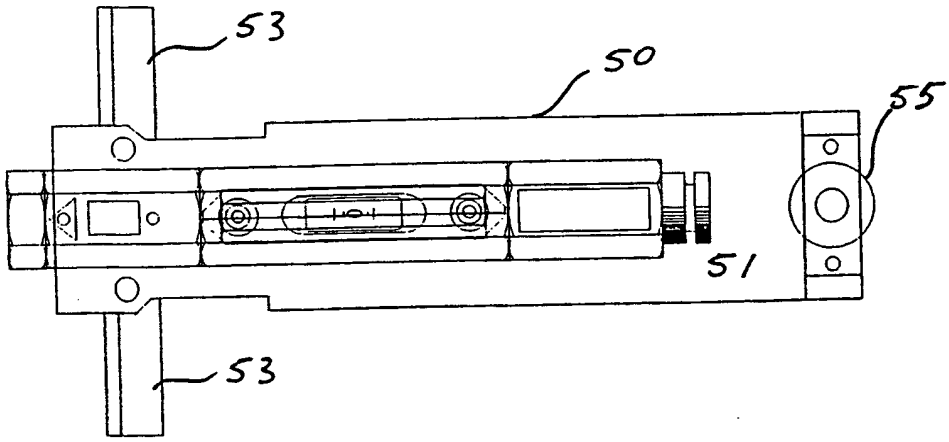

FIG 12

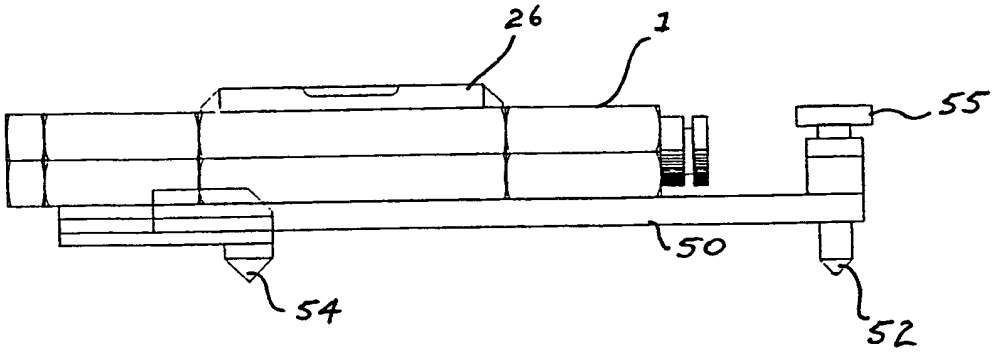

FIG 13

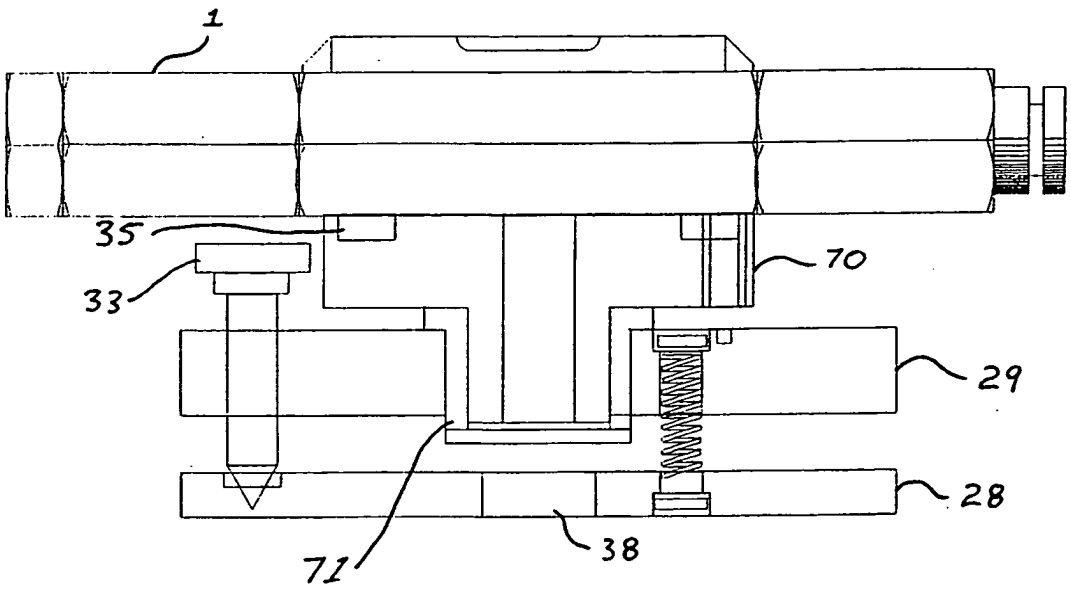

FIG 14

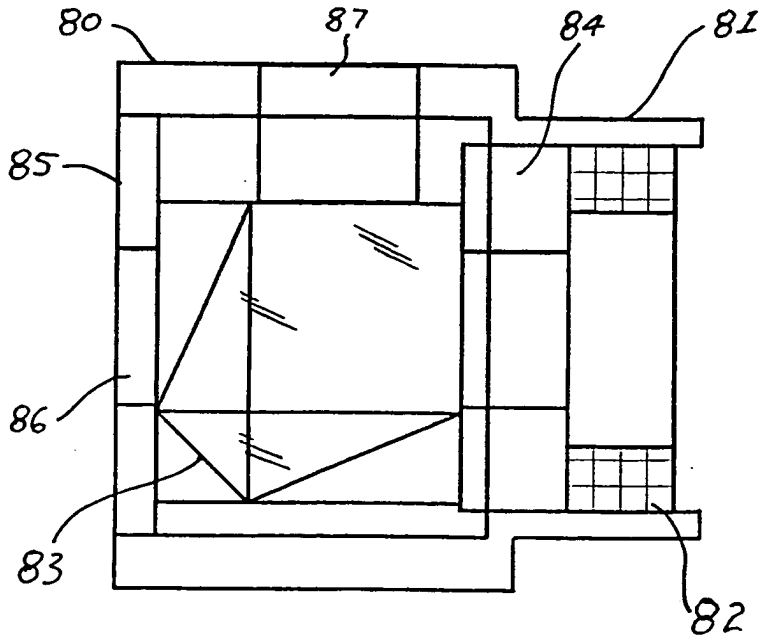

FIG 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 94/00557

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl.[5] G01B 11/27, G01C 5/00 15/00 15/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01B 11/27, G01C 5/00 15/00 15/10, G01M 11/02, G02B 23/00, E21B 47/00.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)
DERWENT: LASER

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	WO,A,91/02217 (HINKEL) 21 February 1991 (21.02.91) See figure 5 and text.	1
X	WO,A,92/20998 (LASER LEVEL SWEDEN AB) 26 November 1992 (26.11.92) See Abstract and figure 1.	1, 3, 4
X	EP,A,0341812 (SPECTRA-PHYSICS INC) 15 November 1989 (15.11.89) See page 5 lines 28-38, page 11 lines 20-39	1, 3, 4
X	EP,A,0401815 (LAWA GMBH) 12 December 1990 (12.12.90) See figure 1 and text	1

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1995 (05.01.95)	9 Jan 1995 (9.1.95)
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	Authorized officer M.E. DIXON Telephone No. (06) 2832194

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU 94/00557

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
X	EP,A,0545321 (ZIMMERMANN) 9 June 1993 (0-9.06.93 See figure 4 and text	1

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Member		
WO,A, 92/20998	AU,A, 17801/92	SE,A, 9101525	
EP,A, 0341812	JP,A, 1304308	US,A, 4852265	US,A, 4912851
EP,A, 0401815	DE,A, 3918865		
			END OF ANNEX